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THE SATELLITE DETERMINATION OF HIGH-ALTITUDE WATER VAPOR

by E. C. May and A. B. Kahle

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THE RAND CORPORATION
Santa Monica, California
for

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THE SATELLITE DETERMINATION OF HIGH-ALTITUDE WATER VAPOR

Barrett and Chung (1962) have discussed the possibility of determining the abundance of high-altitude water vapor by studying the profile of the 1.35-cm resonant water-vapor line in emission. We have modified their method to consider the observation of this emission by a satellite over a perfect reflecting surface, and over land and sea surfaces. We have also extended their study to include apparently more realistic water-vapor distributions at high altitudes.

To facilitate calculation, we have divided the atmosphere into many layers. The emission from a given layer is partially absorbed by each layer it traverses on both the direct and reflected paths to the satellite. We used Van Vleck's absorption equations (1947a,b) to calculate the total power received at the satellite, measured as an antenna temperature. For the temperature and pressure, we used the U. S. Standard Atmosphere (1962). The atmosphere was stratified to match that of Barrett and Chung: intervals of 200 m for the first 3 km, of 500 m up to 18 km, of 1 km up to 30 km, and of 5 km up to 50 km. The satellite was assumed to be at the top of the atmosphere -- in this case, 50 km.

We first considered a water-vapor density distribution (Fig. 1, Line A) similar to that examined by Barrett and Chung, based on the balloon observations by Barrett, et al. (1950). Their observed values have been smoothed and normalized to a total atmospheric water content of $2 g/cm^2$. We arbitrarily assigned the distribution above 30 km. The resulting line profile as observed by a satellite over a perfect reflector (Fig. 2) is strikingly similar to that which Barrett and Chung calculated would be seen at the ground. However, the intensity of the satellite-observed line is twice as great.

We then studied two other water-vapor distributions that appeared to be more realistic. The first (Fig. 1, Line B), a dry stratosphere according to Gutnick (1961), assumes a constant mixing ratio of 5 mg/kg above 15 km. The second (Fig. 1, Line C), a moderately wet stratosphere (Gutnick, 1961) but still drier than that of Barrett, et al., assumes a constant mixing ratio of 13 mg/kg above 13 km. Both retain the exponential distribution below the tropopause that was used in the previous calculation. The sharp peak in the resulting line profile almost completely disappears for these stratospheric humidities (Figs. 3 and 4), although it can still be seen on a more expanded scale. (See insets.)

Barrett and Chung thus appear to be correct in ascribing their calculated peak to anomalously high water vapor at altitudes above 15--20 km. One can clearly see that even a "moderately wet" stratosphere creates no appreciable peak if the distribution is reasonably normal. Since the validity of the anomalous moist stratospheres viewed by early balloon flights is now in doubt (Mastenbrook, 1963), such sharp peaks in the profile as predicted by Barrett and Chung may never be observed. But if they are, they should definitely indicate that these unusual conditions do occur.

We then made calculations for a satellite looking at a 300°K background earth, assuming for oceans a reflectivity of 0.6 and a corresponding emissivity of 0.4 (Meeks, 1963) and for land a reflectivity of 0.1. We used the driest water-vapor density distribution (Fig. 1, Line B). Figure 5 shows the resulting profiles, in which the emission and absorption tend to cancel each other, greatly diminishing the observable peak.

Satellites do not, therefore, appear feasible for this kind of microwave observation, despite the obvious advantages that would accrue from their world-wide coverage. Surface observations are clearly preferable, at least as a start, because they are much easier and because the small peak emission expected would be more clearly defined against the cold background of space. Whether such observations will in fact give useful information about humidity and temperature in the upper atmosphere remains to be seen.

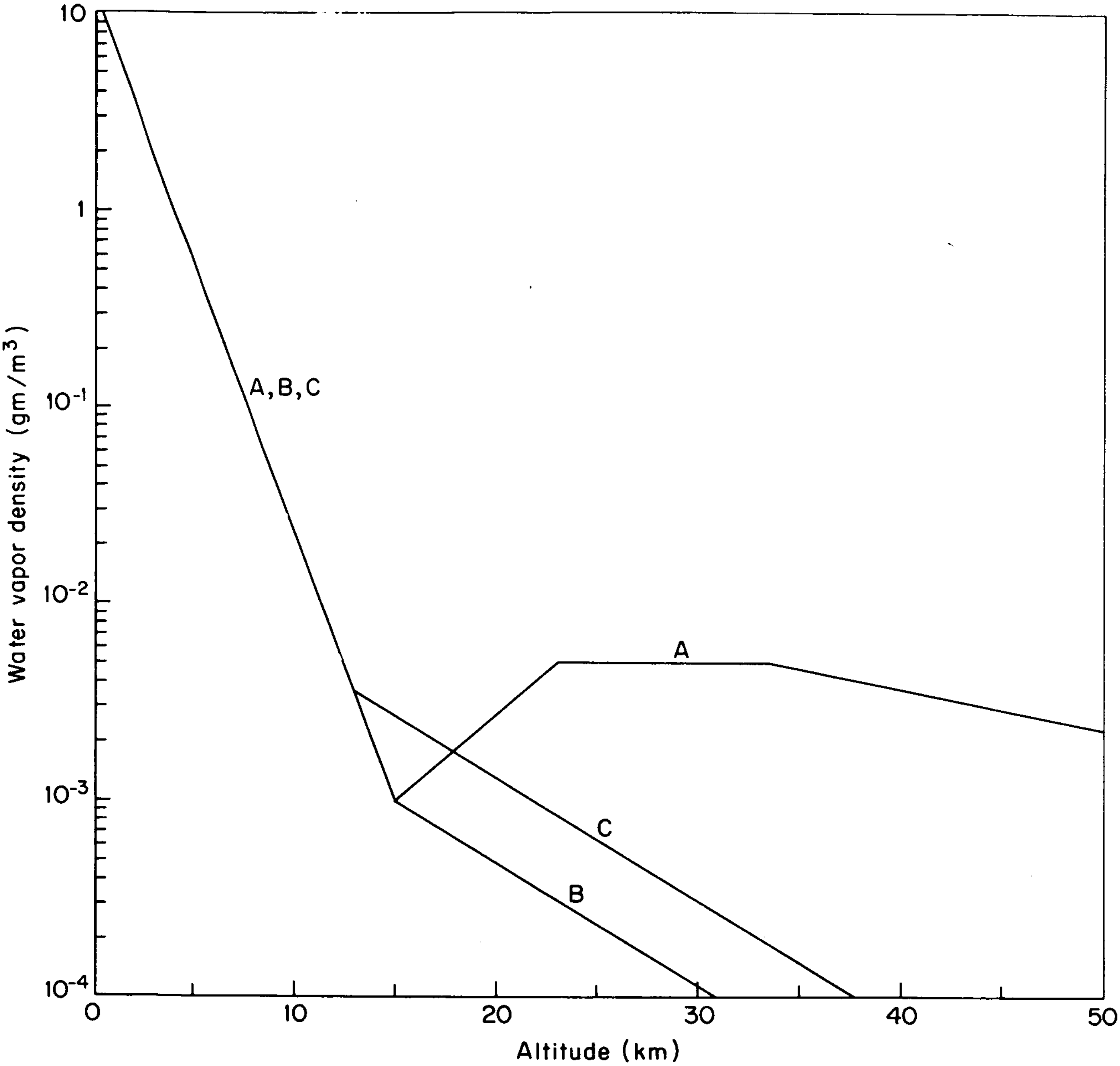

Fig. 1 Water-vapor distributions

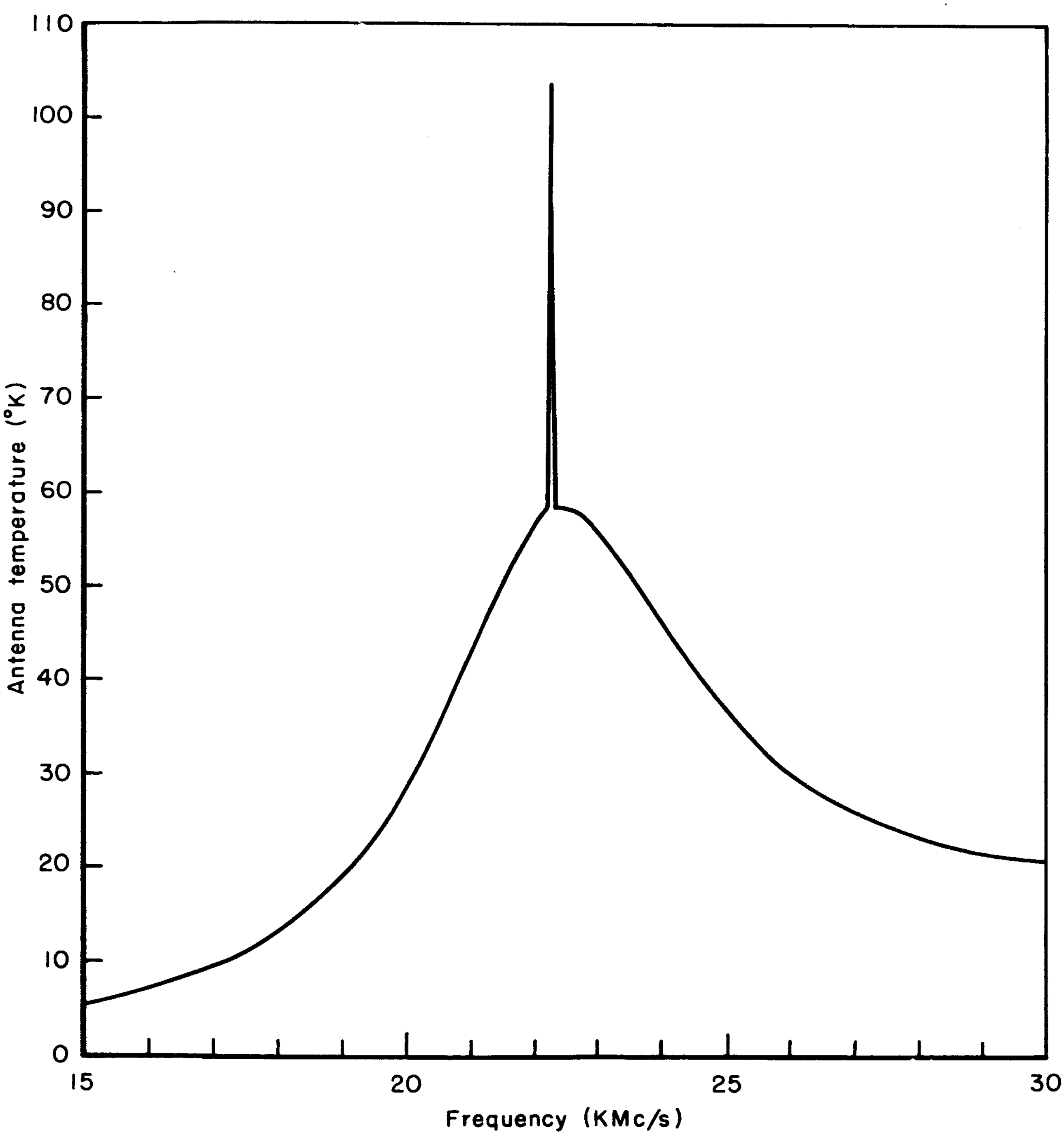

Fig. 2 Line profile computed using water-vapor distribution A, over a perfect reflector

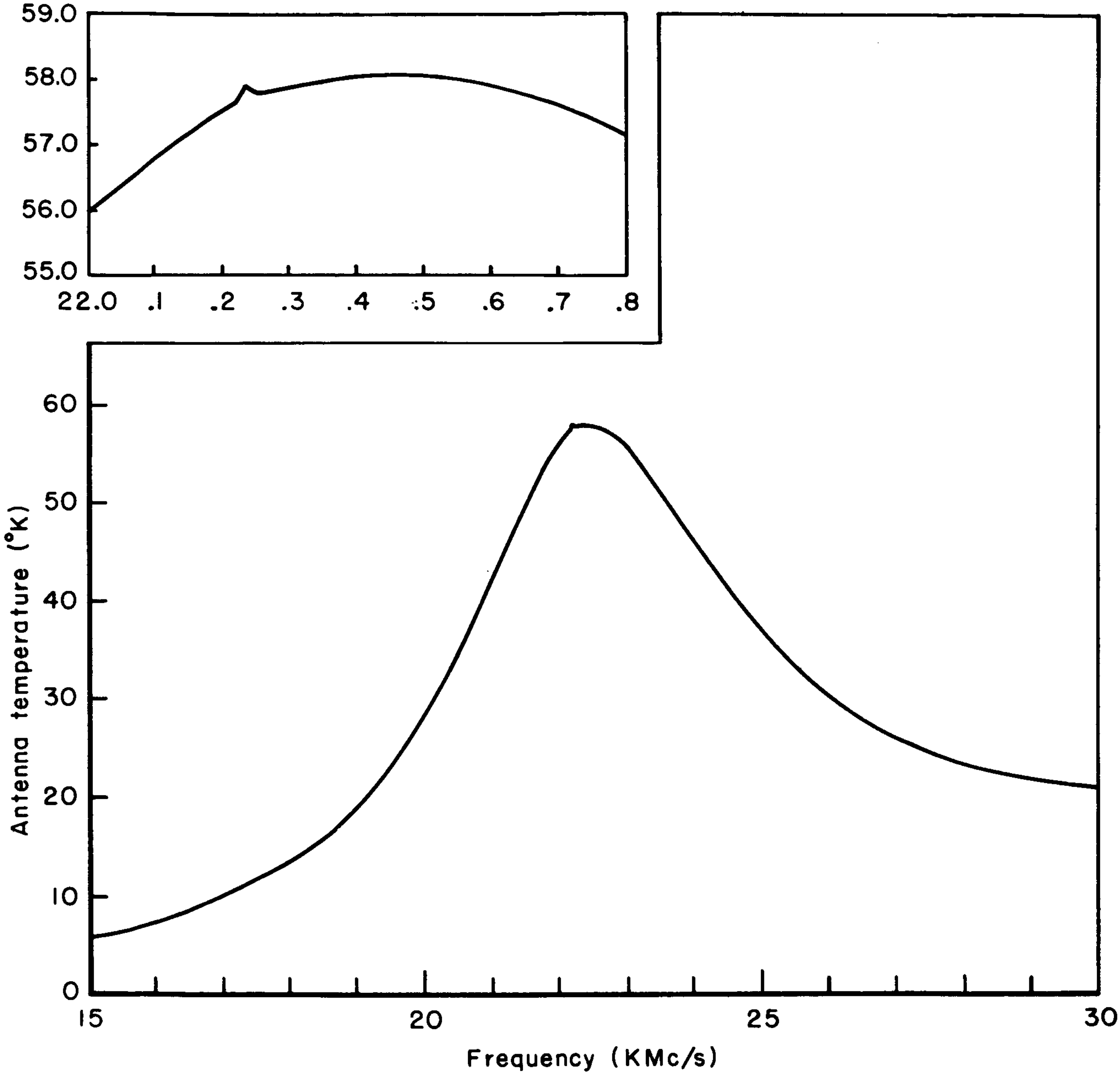

Fig. 3 Line profile computed using water-vapor distribution B, over a perfect reflector

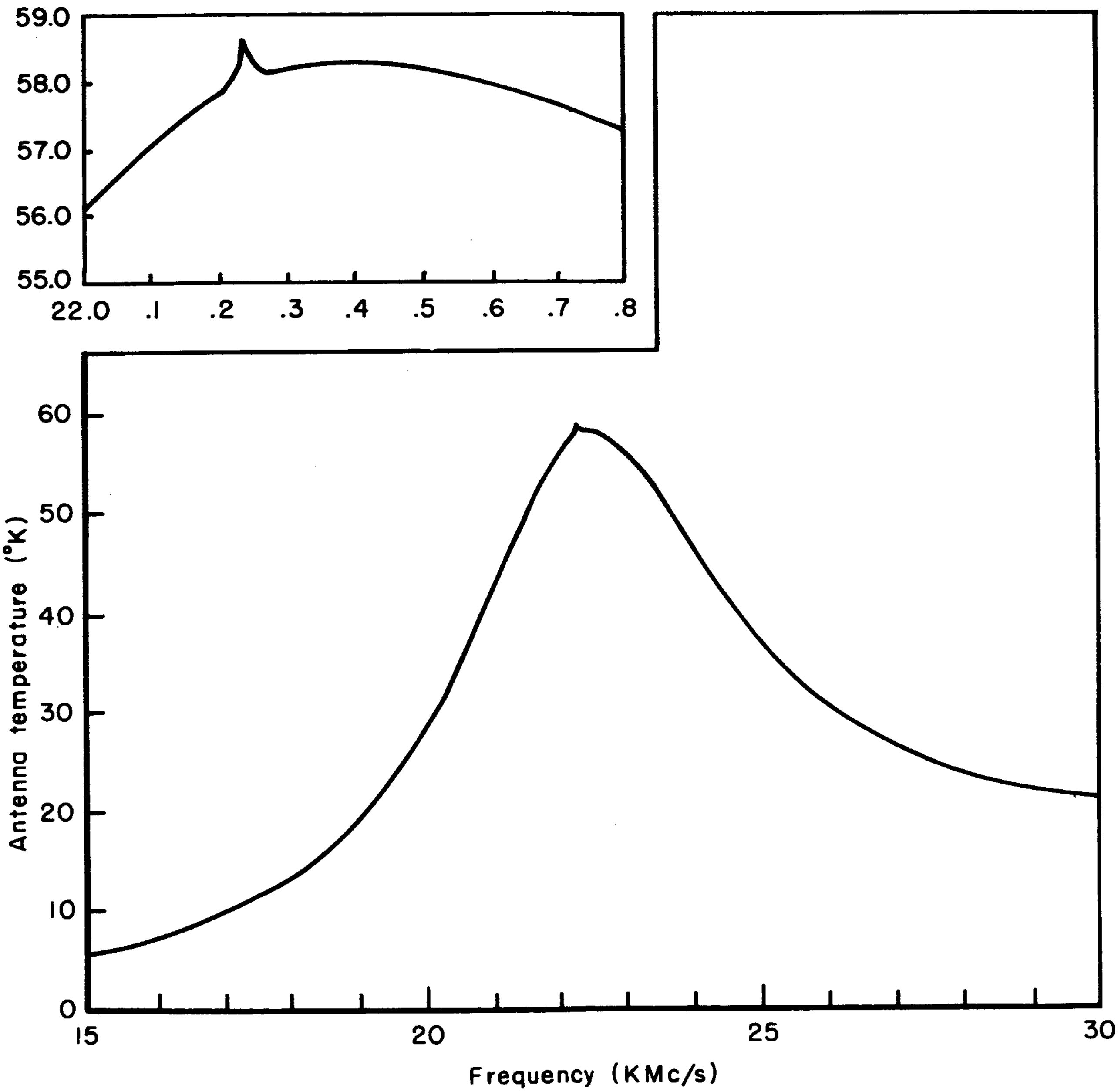

Fig. 4 Line profile computed using water-vapor distribution C, over a perfect reflector

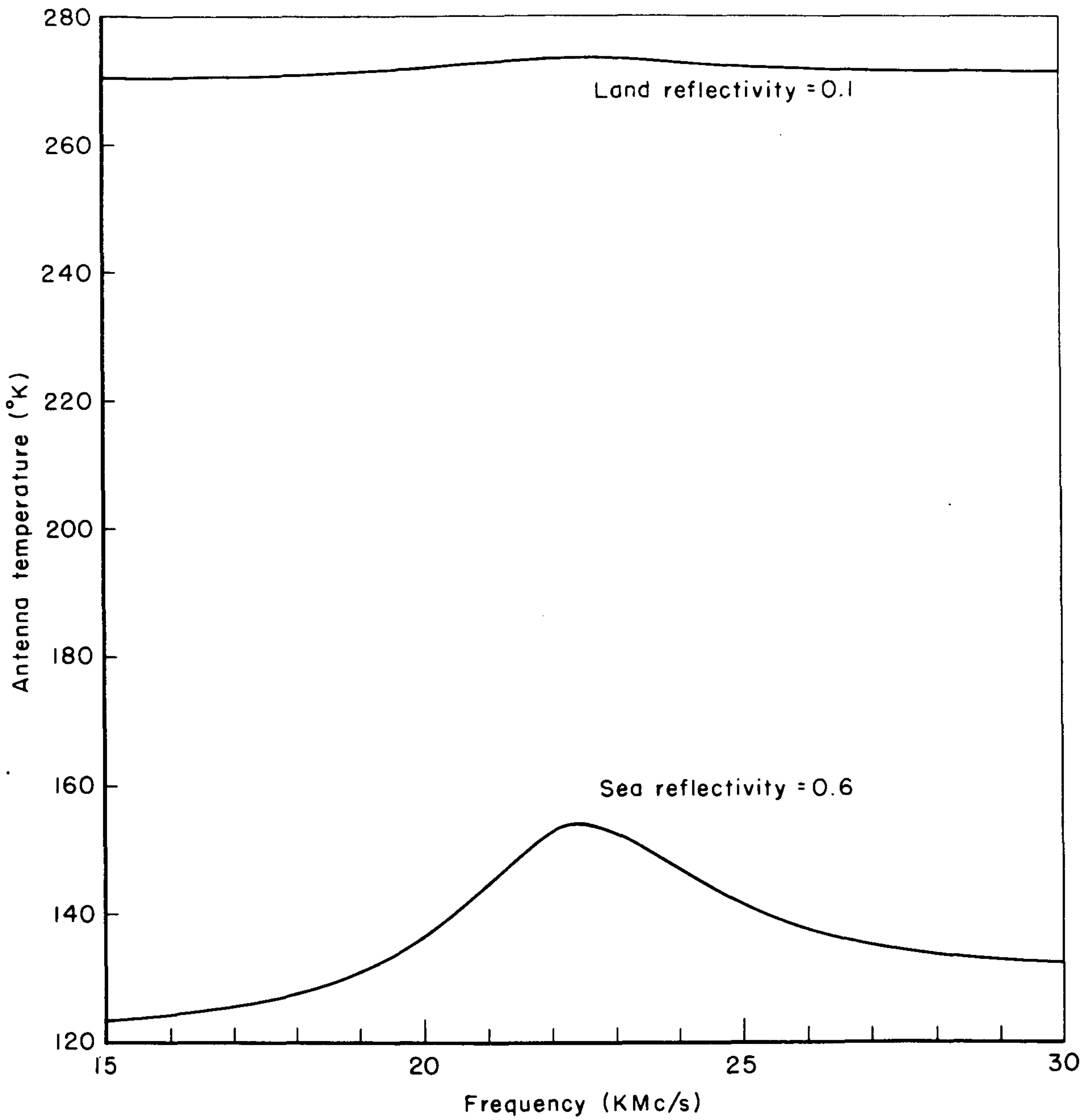

Fig. 5 Line profile computed using water-vapor distribution B, over land and sea

REFERENCES

Barrett, A. H., and V. K. Chung, "A Method for the Determination of High-Altitude Water-Vapor Abundance from Ground-Based Microwave Observations," J. Geophys. Res., 67, 4259-4266, 1962.

Barrett, E. W., L. R. Herndon, and H. J. Carter, "Some Measurements of the Distribution of Water Vapor in the Stratosphere," Tellus, 2, 302-311, 1950.

Gutnick, M., "How Dry is the Sky?" J. Geophys. Res., 66, 2867-2872, 1961.

Mastenbrook, H., The Status of Water Vapor Observations above 20 km and Implications as to the General Circulation; paper delivered at the Upper Atmosphere Meteorology Symposium, I.U.G.G., Berkeley, California, August 21, 1963.

Meeks, M. L., "Measurement of Sea State," in Y. H. Katz (ed.), The Application of Passive Microwave Technology to Satellite Meteorology: A Symposium, RM-3401-NASA, The RAND Corporation, p. 175, August 1963.

U. S. Standard Atmosphere, 1962, National Aeronautics and Space Administration, U. S. Air Force, and U. S. Weather Bureau, Washington, D. C., 1962.

Van Vleck, J. H., "The Absorption of Microwaves by Oxygen," Phys. Rev., 71, 413-424, 1947a.

Van Vleck, J. H., "The Absorption of Microwaves by Uncondensed Water Vapor," Phys. Rev., 71, 425-433, 1947b.

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